# Improving the reliability of the resist outgas contamination test

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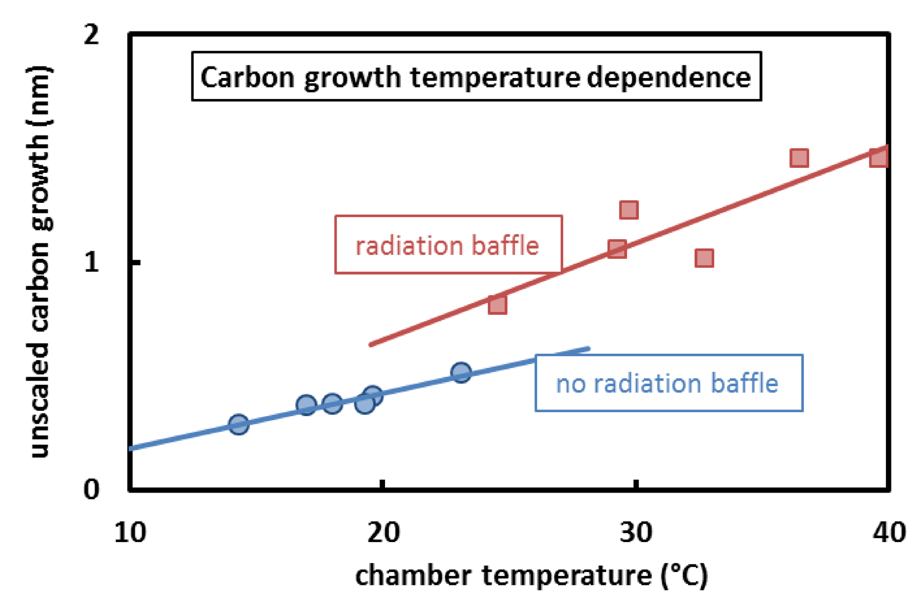
## Abstract

The standard protocol to determine the outgas-contamination potential of an EUV resist has four steps: (1) simultaneously irradiating a witness sample and a resist-coated wafer with either EUV photons or proxy electrons; (2) using ellipsometry to measure the resulting carbon growth on the witness sample, (3) cleaning the witness sample with atomic hydrogen, and (4) using XPS to detect residual non-carbon contaminants on the cleaned witness sample. An essential requirement for the reliability of the test is to ensure that the intensity of the electrons or photons on the witness sample is sufficiently high that the carbon growth is mass limited (independent of intensity). The recent increase in the allowable carbon growth from 3 nm to 10 nm may require higher witness sample intensities to ensure mass-limited growth for resists with greater contamination rates. We describe our efforts to meet this challenge by changing the EUV spectrum used in the NIST tool. We also discuss our improvements in the stability and uniformity of the chamber temperature. We observed that the carbon growth thickness increases approximately linearly with temperature between 15 °C and 30 °C with a slope that varies significantly with resist.



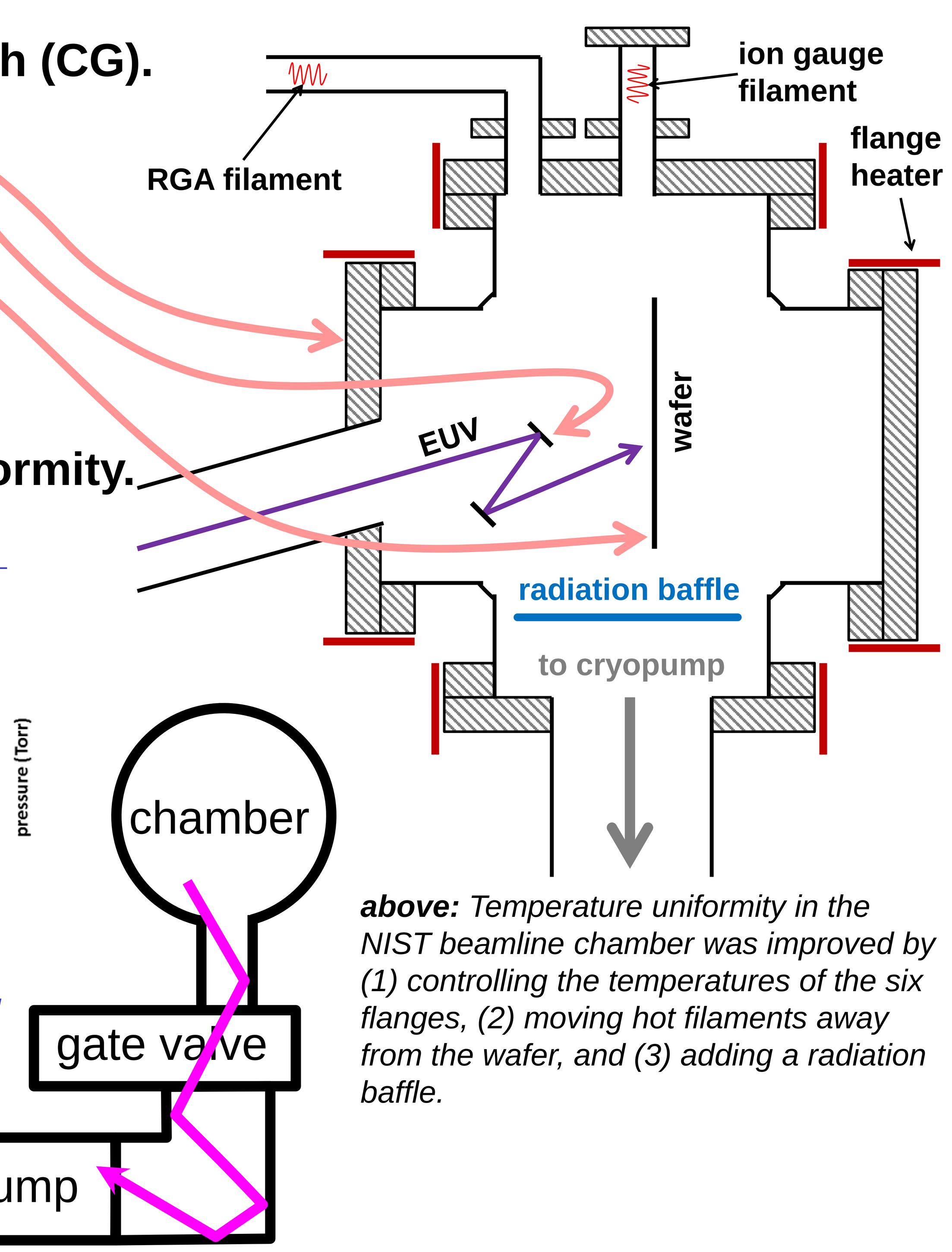

## Improving the temperature control

### Temperature of three places affects carbon growth (CG).

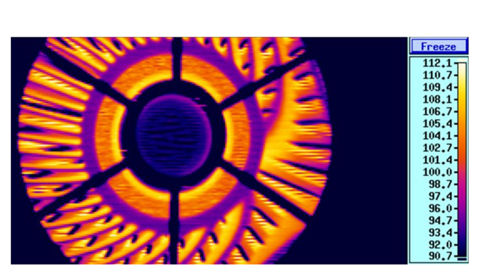
### Step 1: Stabilize the chamber temperature.

Insulate the chamber.
Control the temperatures of the six chamber flanges.

### Step 2: Identify and reduce temperature non-uniformity.

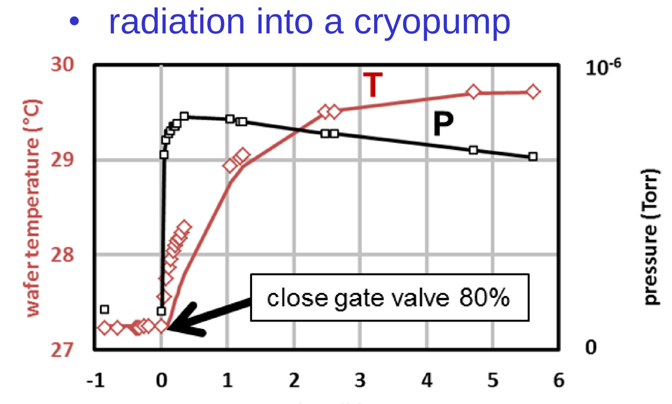



**causes of heating**
- exposure to EUV or e-gun
- friction in motion stages
- radiation from hot filaments
- radiation from a turbo pump



*above:* *A turbomolecular pump under no load (high vacuum) will typically have a rotor temperature of 40 – 60 °C. [Silvio Giors, Agilent R&D product manager, 2009-2014]*

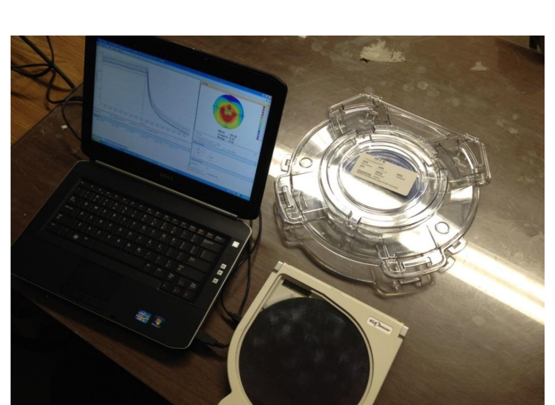
**causes of cooling**
- radiation into a cryopump




*above:* *Partially closing the gate valve showed that the cryopump was cooling the wafer.*
*right:* *Althoughhe chamber does not directly see the cryopump, reflections may be important.*

*above:* *Temperature uniformity in the NIST beamline chamber was improved by (1) controlling the temperatures of the six flanges, (2) moving hot filaments away from the wafer, and (3) adding a radiation baffle.*

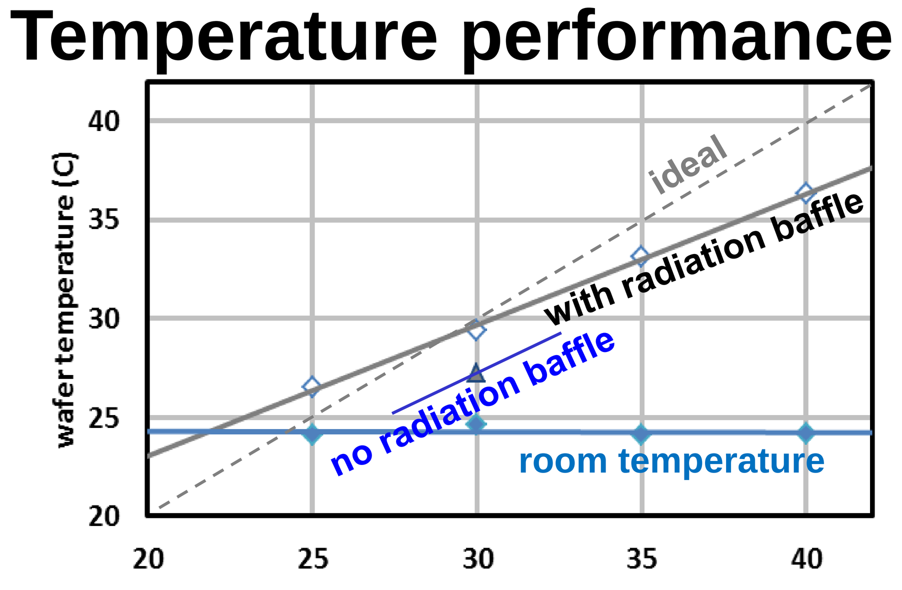
## Temperature measurement tools



**Commercial instrumented wafer (courtesy of EIDEC)**

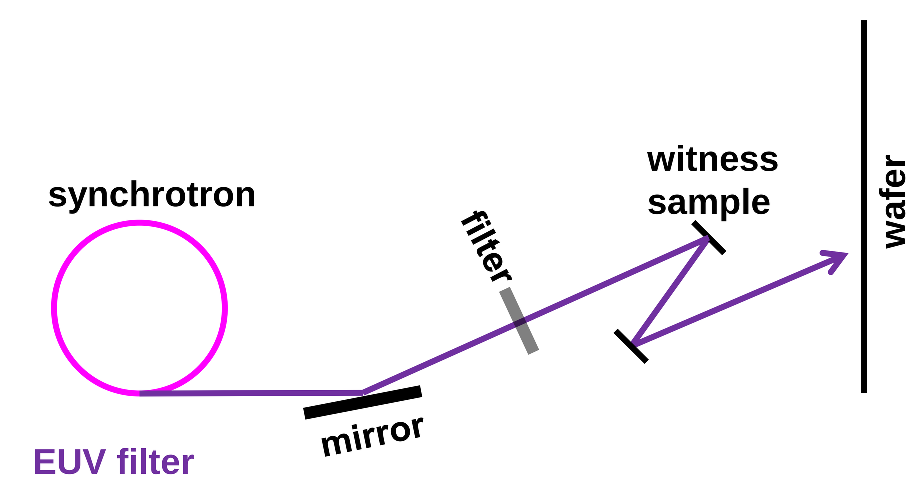
**Thermistor glued to wafer**

## Temperature performance

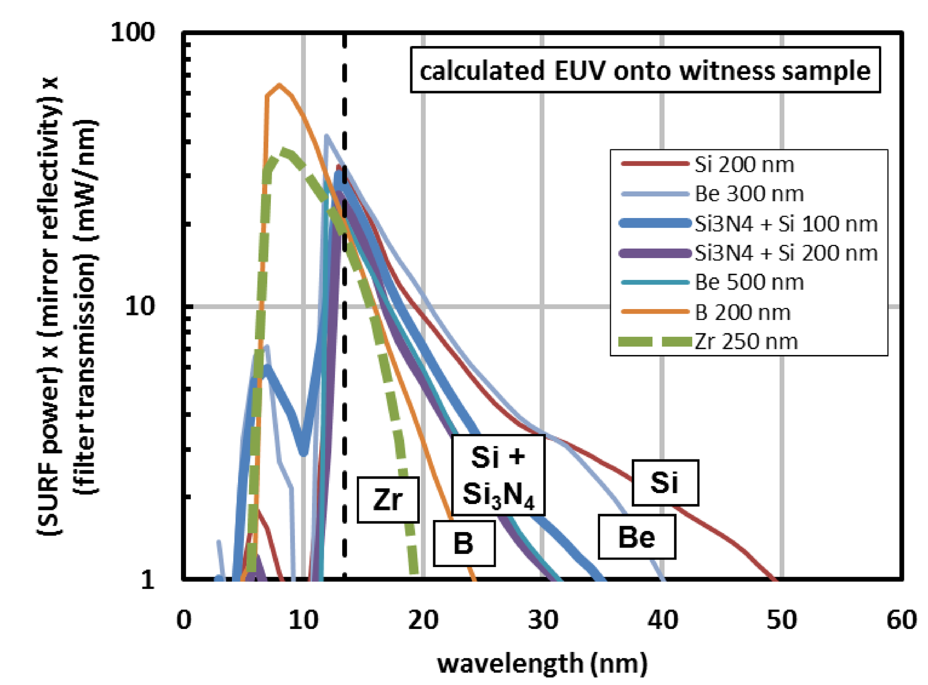



## Increasing the damage rate by changing the incident spectrum

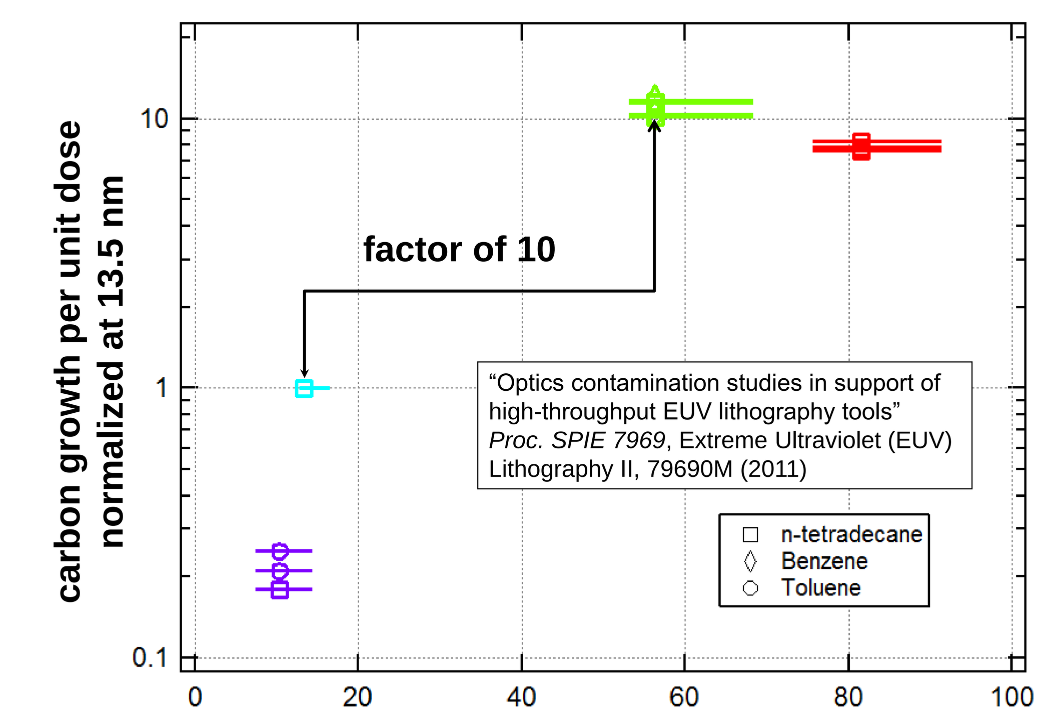
| | |
|---|---|
| **Ideal CG test** | 13.5 nm EUV on wafer and sample |
| **Actual CG test** | 13.5 nm EUV on wafer and 7-20 nm **broadband** on sample |

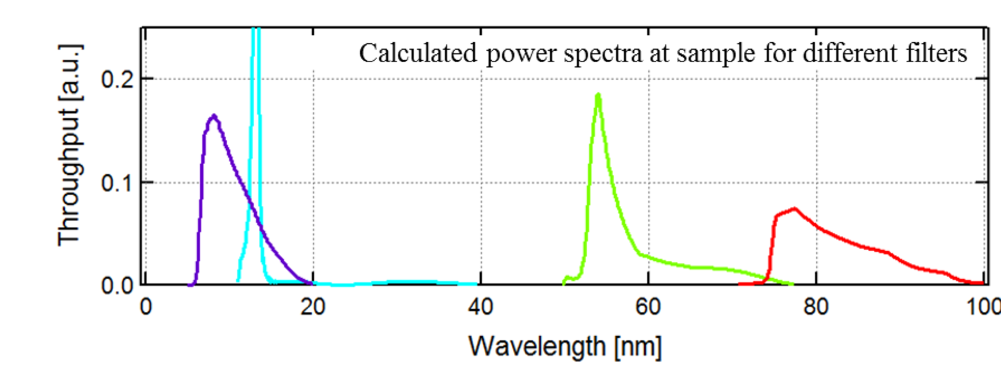



**EUV filter**
- Protects the synchrotron from resist contamination.
- Removes deep UV.
- Decreases EUV power on the sample.
- Determines the incident spectrum.




**Broadband EUV is helpful**
- Gives more power to help achieve contamination limited regime (CLR).
- In the CLR, the CG is insensitive to the spectrum.
- Increased CG limit ➔ more contaminating resists ➔ more EUV power for CLR



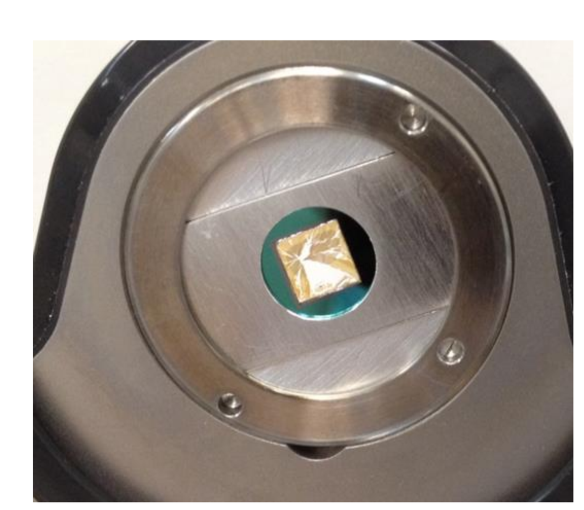




**CLR can be achieved by:**
- increasing broadband EUV power
- shifting the spectrum to the red (see above)
- either or both can be achieved by changing the filter material

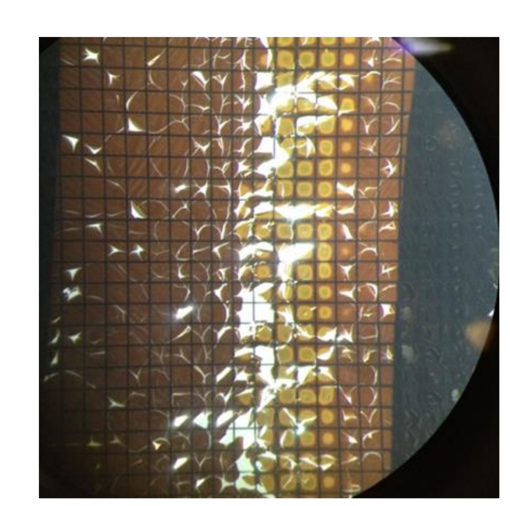
## Preliminary results

### EUV damages the filter

| material | nm thick | mm x mm area | type | 1 h exposures lifetime |
|---|---|---|---|---|
| Zr | 250 | 6 x 16 | film + mesh | 20 |
| Si | 250 | 6 x 16 | film + mesh | 0 |
| Si | 200 | 5 x 5 | polysilicon | 0.1 (2 short exposures) |
| B | 118 | 6 x 16 | film + mesh | 0 |

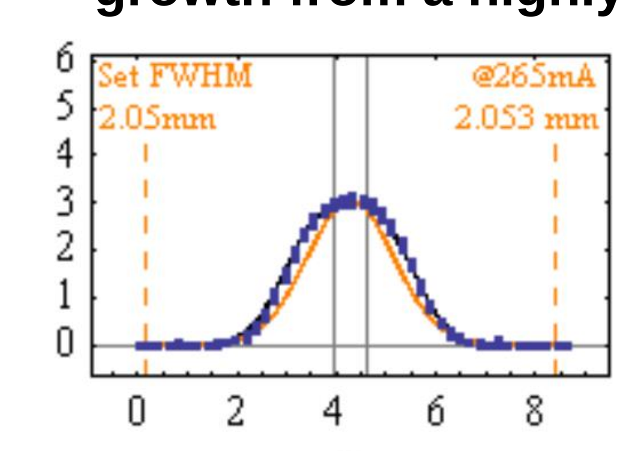


**damaged Si filter (polysilicon)**

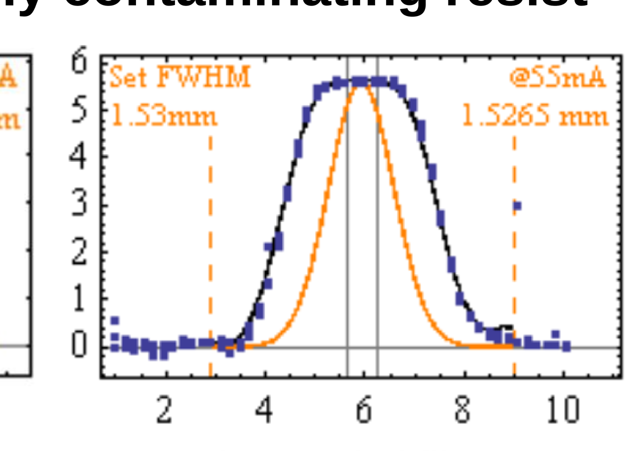


**damaged Si filter (film + mesh)**

### EUV through a (damaged) Si filter caused contamination-limited carbon growth from a highly contaminating resist




**Zr filter**




**damaged Si filter**

*above:* *The additional EUV admitted by the damaged Si filter had two effects: (1) The EUV at much longer wavelengths reached the resist-coated wafer to cause more outgassing. (The RGA spectrum above 150 amu was ~2 times larger.) (2) As indicated by the flat-top profile, the CG grown on the witness sample was in the CLR.*